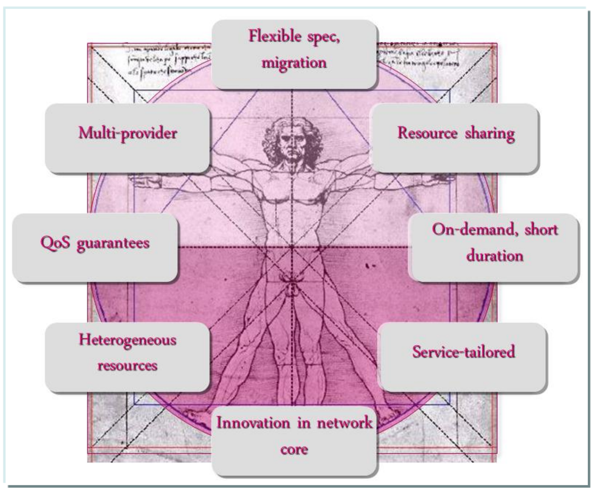
CloudNets: Virtual Networking Cloud Resources (Prototype, Algorithms, Economics)

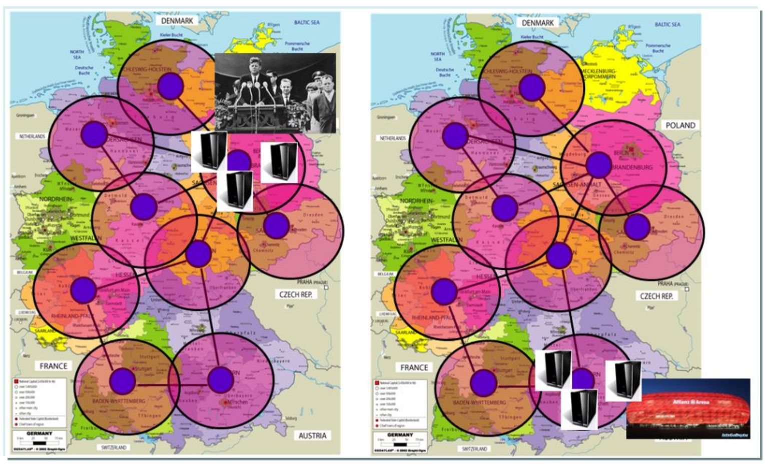
Anja Feldmann, Carlo Fürst, Johannes Grassler, Arne Ludwig, Matthias Rost, Gregor Schaffrath, Stefan Schmid

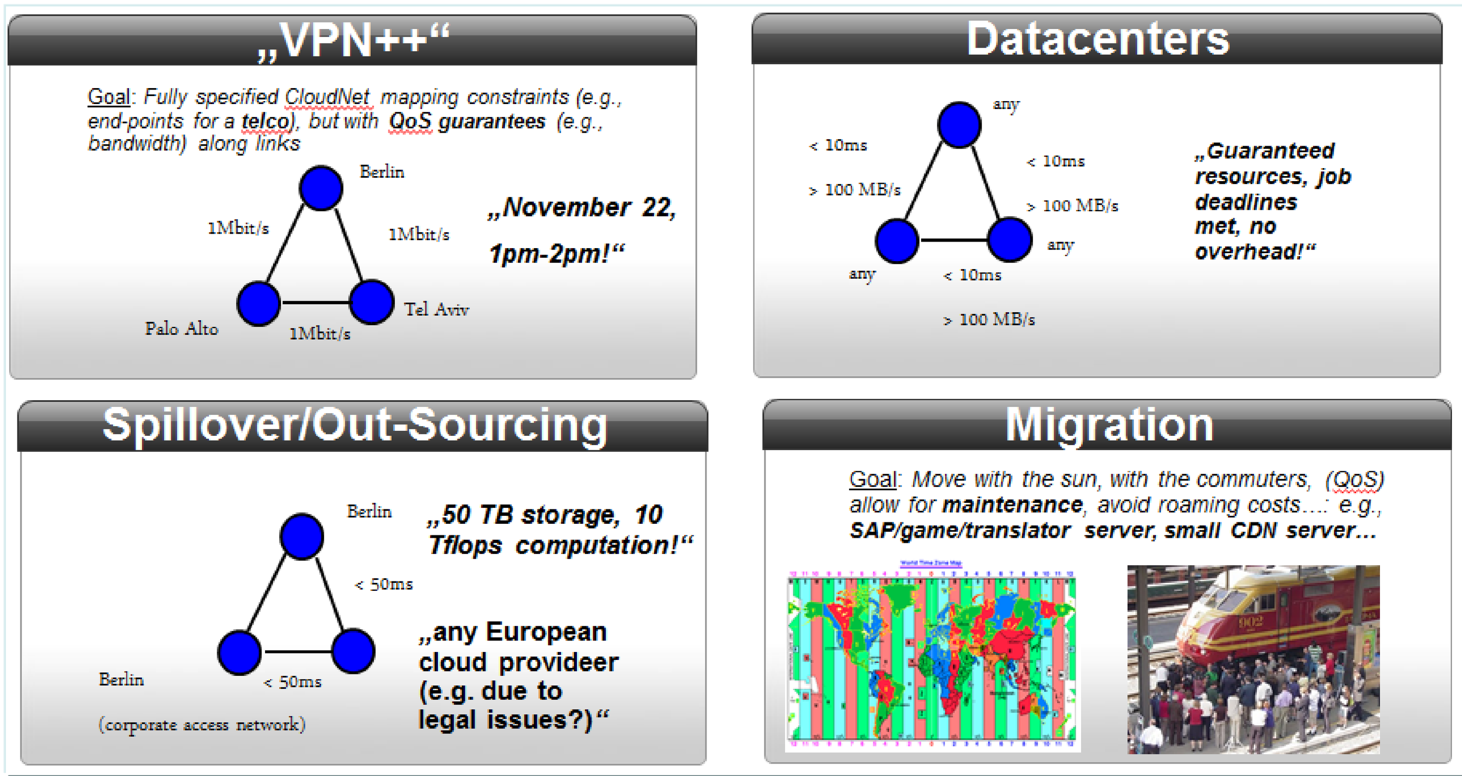
(plus external collaborators at DoCoMo, at Uni Wroclaw and at Uni Tel Aviv)

1. Vision & Use Cases

CloudNets as flexibly specifiable, service-specific and adaptive virtual networks connecting heterogeneous resources.







2. FleRD: A Flexible CloudNet and Resource Description Language

Specification, communication and internal representation of CloudNets requires a Resource Description Language (RDL). Our FleRD language is flexible / extensible and allows for vagueness and omission / hiding of details. Specification flexibility is exploited during embedding.

Fig. 1. CloudNet specification for a Web Service: two virtual servers handle at least 100 sessions. Node and link placement is subject to black and white listing.

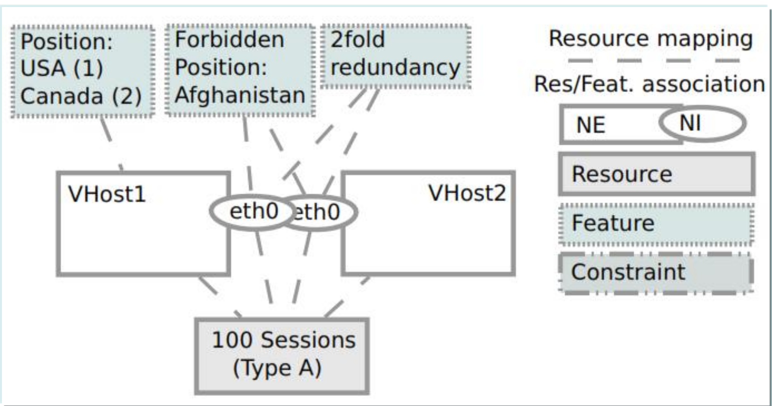
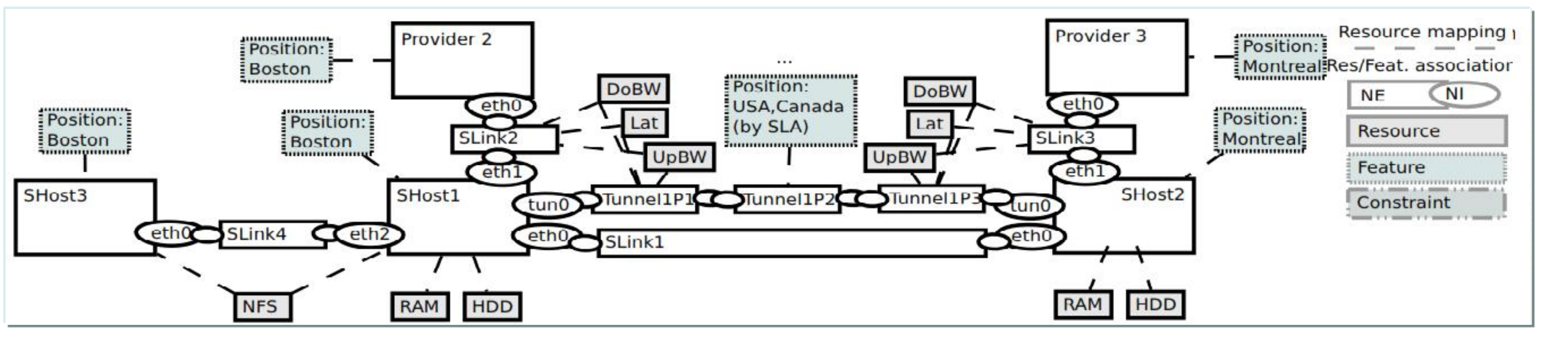
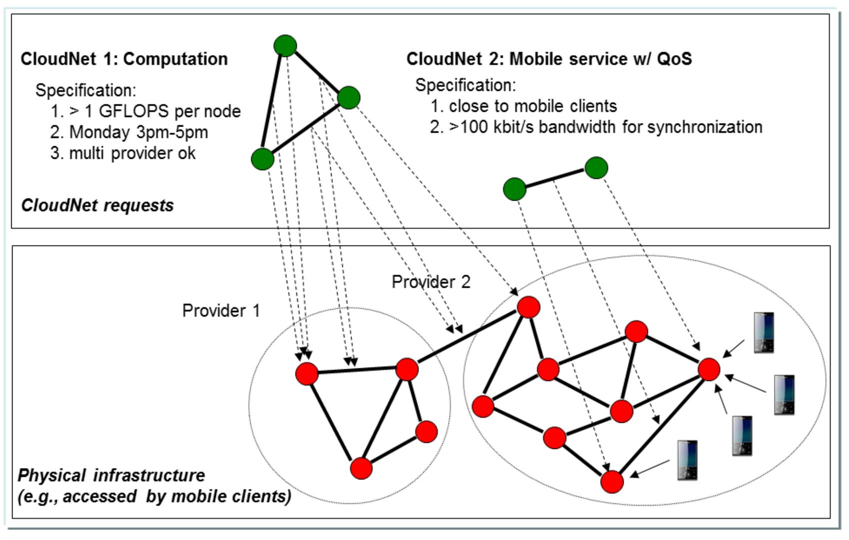


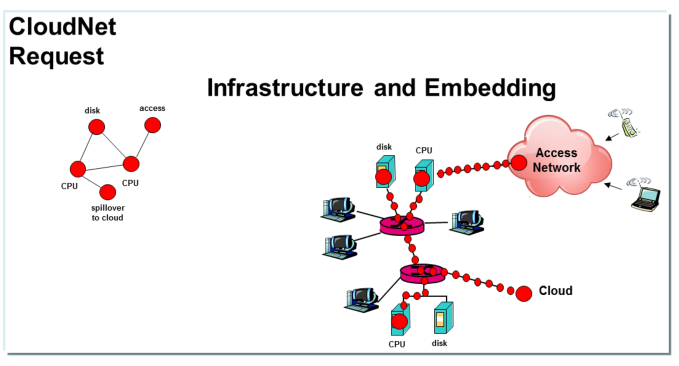
Fig. 2. Realization over two providers.



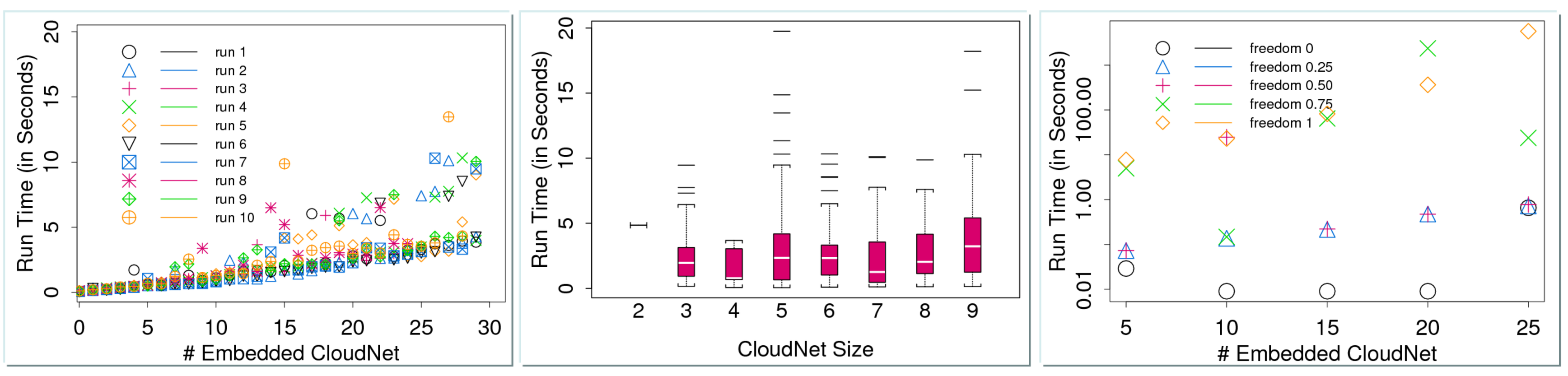
3. Optimizing Long-Lived CloudNet Embeddings with Migrations

Our CloudNet embedding algorithm supports very general CloudNets. Concretely, it supports all kinds of links (e.g., full-duplex, half-duplex, or asymmetric links), various migration cost models, and also different objective functions (e.g., for load balancing or energy conservation, …). We believe that often a more rigorous and time-consuming optimization may pay off for long-lived CloudNets. Our approach is based on Mixed Integer Programming.





Time complexity of embedding depends on load, CloudNet size as well as the flexibility in the CloudNet specification:



4. Online Algorithms and Competitive Analysis: Dealing with Demand Uncertainty without Problematic Prediction Models!

Specification, communication and internal representation of CloudNets requires a Resource Description Language (RDL). Our FleRD language is flexible / extensible and allows for vagueness and omission / hiding of details. Specification flexibility is exploited during embedding.

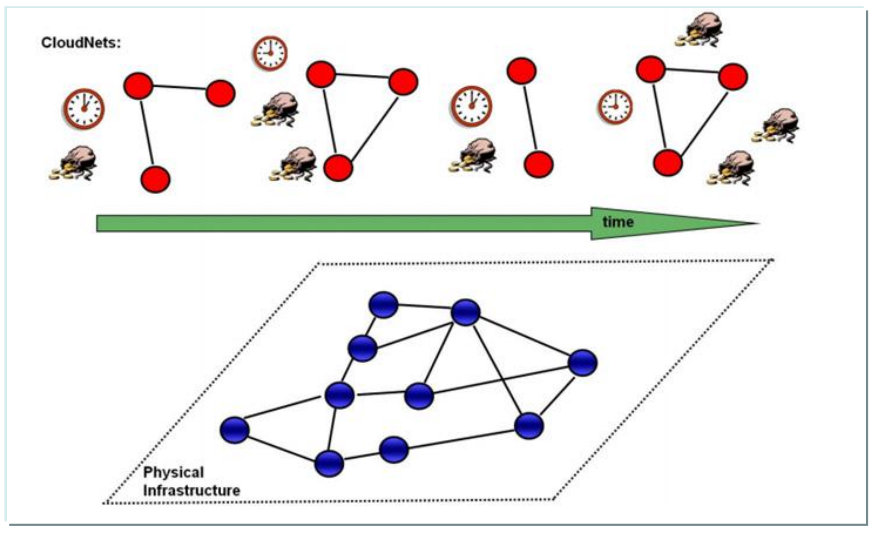
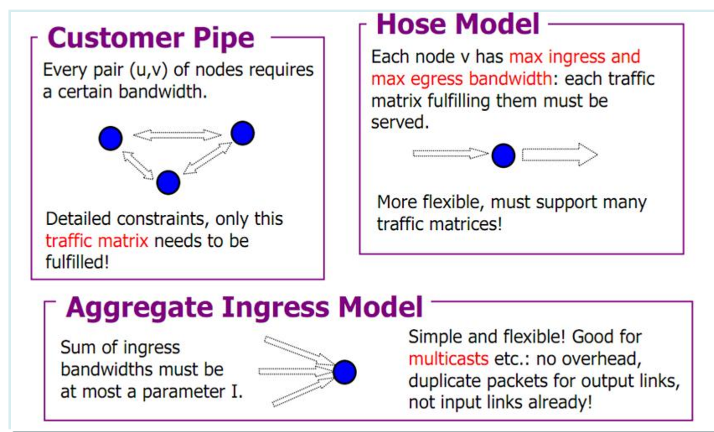


Fig. 3. Arbitrary CloudNet requests arrive over time, with different requirements (traffic model, duration, …) and benefits. Which ones to accept online?



Answer can be computed with online **primal-dual approach** framework. Gives **worst-case guarantees**!

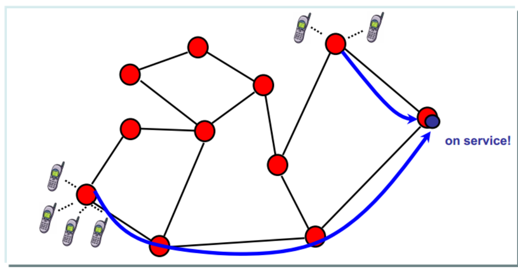
(I)	(II)
$\min Z_j^T \cdot \mathbf{1} + X^T \cdot C \;\; s.t.$ $Z_j^T \cdot D_j + X^T \cdot A_j \geq B_j^T$ $X, Z_j \geq \mathbf{0}$	$\max B_j^T \cdot Y_j \;\; s.t.$ $A_j \cdot Y_j \leq C$ $D_j \cdot Y_j \leq \mathbf{1}$ $Y_j \geq \mathbf{0}$

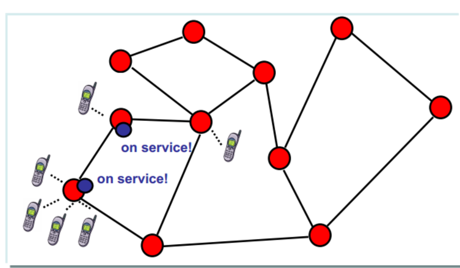
Algorithm 1. The General Integral (all-or-nothing) Packing Online Algorithm (GIPO).

Upon the jth round:

1. $f_{j,\ell} \leftarrow \text{argmin}\{\gamma(j,\ell) : f_{j,\ell} \in \Delta_j\}$ (oracle procedure)
2. If $\gamma(j,\ell) < b_j$ then, (accept)
   (a) $y_{j,\ell} \leftarrow 1$.
   (b) For each row e : If $A_{e,(j,\ell)} \neq 0$ do
   $$x_e \leftarrow x_e \cdot 2^{A_{e,(j,\ell)}/c_e} + \frac{1}{w(j,\ell)} \cdot (2^{A_{e,(j,\ell)}/c_e} - 1).$$
   (c) $z_j \leftarrow b_j - \gamma(j,\ell)$.
3. Else, (reject)
   (a) $z_j \leftarrow 0$.

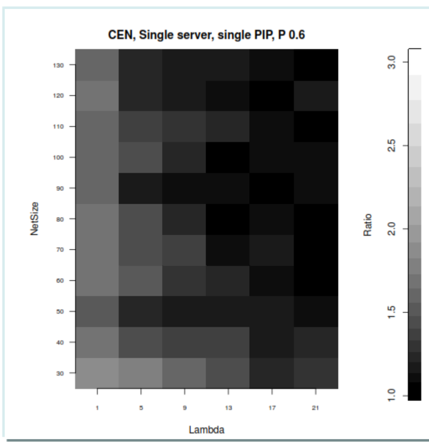
Also the question where to migrate under demand uncertainty is an online problem!

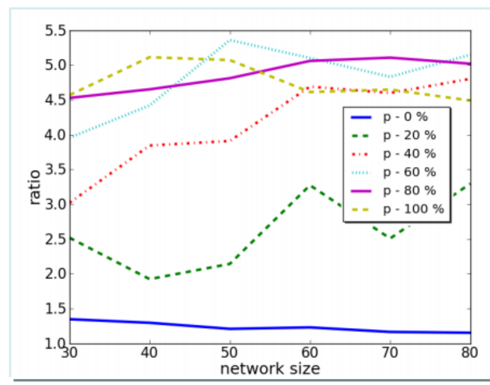


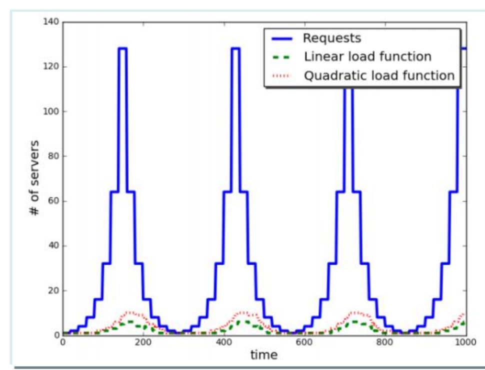


CEN divides time into *epochs* consisting of one or multiple *phases* between which CEN migrates. Again, we have counters $C(v)$ for each node v that are set to zero at the beginning of an epoch. These counters accumulate the access costs of an epoch if the server was permanently located at v. Henceforth, we will call all nodes v for which at time t, $C(v) < \beta/40$, *active nodes* at time t. Assume that algorithm CEN is currently at some node v. CEN remains at this node until it accumulated there access costs of β. Then, a new phase starts, and CEN computes the *gravity center* w, i.e., the "center" of the currently active nodes. Formally, let d denote the shortest path metric (w.r.t. access costs) on the network G. The gravity center of a subset $V' \subseteq V$ of nodes is defined as the (not necessarily unique) node $\mathcal{G}(V') = \arg\min_{v \in V'} \sum_{u \in V'} d(u,v)$. (Ties are broken arbitrarily.) CEN migrates to w and a new phase starts. If there is no active node left, the epoch ends.

Evaluation: Deterministic worst-case guarantees compared to optimal solution where entire demand is known in advance! And simulations…







5. Business Roles, Prototype and Migration Demonstrator

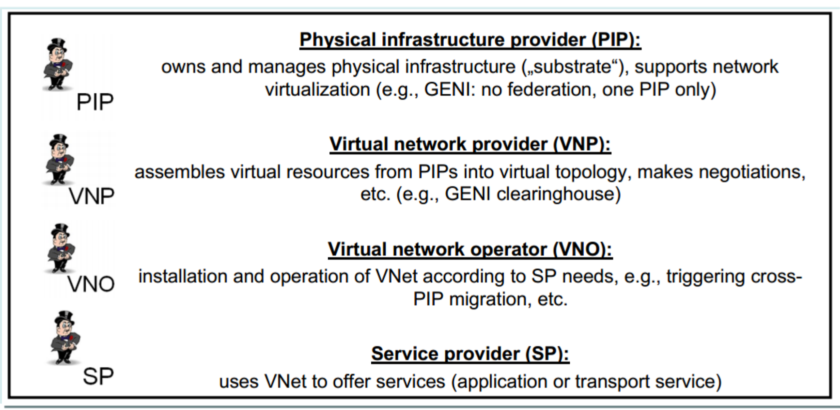


Fig. 4. The four roles: Service Provider (SP), Virtual Network Operator (VNO), Virtual Network Provider (VNP), and Physical Infrastructure Provider (PIP). Specification / QoS guaranteed via contracts.

Current prototype based on VLANs. Demo of migrating video server to improve QoS on YouTube:

http://www.youtube.com/watch?v=lIJce0F1zHQ

Literature

Even, G. & Medina, M. & Schaffrath, G. & Schmid, S. (**2012**), Competitive and Deterministic Embeddings of Virtual Networks, *in* 'Proc. ICDCN', **Best Paper Award**.

Arora, D. & Bienkowski, M. & Feldmann, A. & Schaffrath, G., & Schmid, S. (**2011**), Strategies for Intra and Inter Provider Service Migration in Virtual Networks, *in* 'Proc. IPTComm'.

Arora, D. & Feldmann, A. & Schaffrath, G., & Schmid, S. (**2011**), On the Benefit of Virtualization: Strategies for Flexible Server Allocation, *in* 'Proc. USENIX Hot-ICE'.

Bienkowski, M. & Feldmann, A. & Jurca, D. & Kellerer, W. & Schaffrath, G., & Schmid, S. & Widmer, J. (**2011**), Competitive Analysis for Service Migration in VNets, *in* 'Proc. SIGCOMM VISA'.

For further information

Please contact **Stefan Schmid** (stefan.schmid@tu-berlin.de). This poster as well as more information on this and related projects can be obtained at our project website: http://www.net.t-labs.tu-berlin.de/~stefan/virtu.shtml